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# AN AVIAN VERTEBRA FROM THE CONTINENTAL CRETACEOUS OF MOROCCO, AFRICA[1]

(With 7 figures)

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ABSTRACT: We report the occurrence of an isolated avian dorsal vertebra in Cretaceous strata of Morocco. The specimen was found near Erfoud oasis in the Tafilalt region of southeastern Morocco preserved in a reddish sandstone. It has a large neural canal (ratio height neural canal/cranial articulation surface = 0.67), a feature regarded as a synapomorphy of Aves. Compared to dorsal vertebrae of other Mesozoic birds, the Moroccan specimen is most similar to *Rahona ostromi* from the Late Cretaceous of Madagascar. The absence of a developed pleurocoel, however, indicates that it belongs to a distinct taxon. Although the correct phylogenetic position of this specimen within Aves cannot be reliably determined, it most likely represents a basal group. This specimen is significant because it represents the second osteological evidence of a Cretaceous bird from northern Gondwana.

Key words: fossil bird, Late Cretaceous, Morocco, Africa.

RESUMO: Uma vértebra aviana do cretáceo continental do Marrocos, África.

Registra-se a ocorrência de uma vértebra dorsal aviana isolada proveniente dos estratos cretácicos do Marrocos. O espécime foi encontrado próximo ao oásis Erfoud na região de Tafilalt no sudoeste do Marrocos, preservado num arenito avermelhado. Possui um amplo canal neural (proporção altura do canal neural/altura da superfície articular cranial = 0.67), uma característica considerada sinapomórfica de Aves. Comparado com vértebras dorsais de outras aves mesozóicas, o espécime marroquino é muito similar à *Rahona ostromi* do Cretáceo Superior de Madagascar. A ausência de um pleurocelo desenvolvido, entretanto, indica que pertença a um táxon distinto. Embora uma correta posição filogenética desse espécime dentro de Aves não possa ser seguramente determinada, ele provavelmente representa um grupo basal. Esse espécime é significante por representar o segundo registro osteológico de uma ave cretácica do norte do Gondwana.

Palavras-chave: ave fóssil, Cretáceo Superior, Marrocos, África.

## INTRODUCTION

The record of Mesozoic birds in Gondwana is quite poor and most of the osteological material is restricted to South America. Skeletal material has been reported from Patagonia, Argentina (CHIAPPE & CALVO, 1994), and fossil feathers have been found in the Santana Formation, Brazil (MARTINS NETO & KELLNER, 1988; KELLNER & CAMPOS, 2000). A few osteological remains are known from other parts of Gondwana, including a tibiotarsus from the Early Cretaceous of Australia attributed to the Enantiornithes (MOLNAR, 1986), appendicular elements of Anseriformes from the Late Cretaceous of Antarctica (NORIEGA & TAMBUSSI, 1995), and skeletal remains of the Enantiornithes from the Late Cretaceous of Lebanon (DALLA VECCHIA & CHIAPPE, 2003). In current Africa, the avian record is limited to footprints (Ellenberg, 1974 and Lockey *et al.*, 1992 *apud* CHIAPPE, 1995) and incomplete limb elements and one partial skeleton from Madagascar (FORSTER *et al.*, 1996; 1998). Here we report the occurrence of an isolated dorsal vertebra (briefly mentioned before - RIFF *et al.*, 2002) from Albo-Cenomanian sandstones of the Kem Kem, found near Erfoud oasis in the Tafilalt region of southeastern Morocco (RUSSELL, 1996), housed in the Canadian Museum of Nature (CMN 50852; cast

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MN 6920-V at the Museu Nacional; Fig.1). The specimen was preserved in a reddish sandstone, deposited under fluvial condition (RUSSELL, 1996), and was prepared by mechanical methods. This deposit furnished the remains of several fossils, including reptilian teeth (KELLNER & MADER, 1997), turtles (GAFFNEY, TONG & MEYLAN, 2002), crocodilomorphs (BUFFETAUT, 1994; BROIN, 2002) and pterosaurs (MADER & KELLNER, 1999; WELLNHOFER & BUFFETAUT, 1999), besides several other vertebrate bones, including dinosaurs, mostly found isolated (RUSSELL, 1996). The majority of the specimens are collected by local people and therefore the exact locality where they were found remains unknown. This is also the case of the avian vertebra described here, which is one of the few remains of this clade from Africa.

## DESCRIPTION

The vertebra is well preserved, despite being incomplete (Figs.2-7). The dorsal surface of the neural

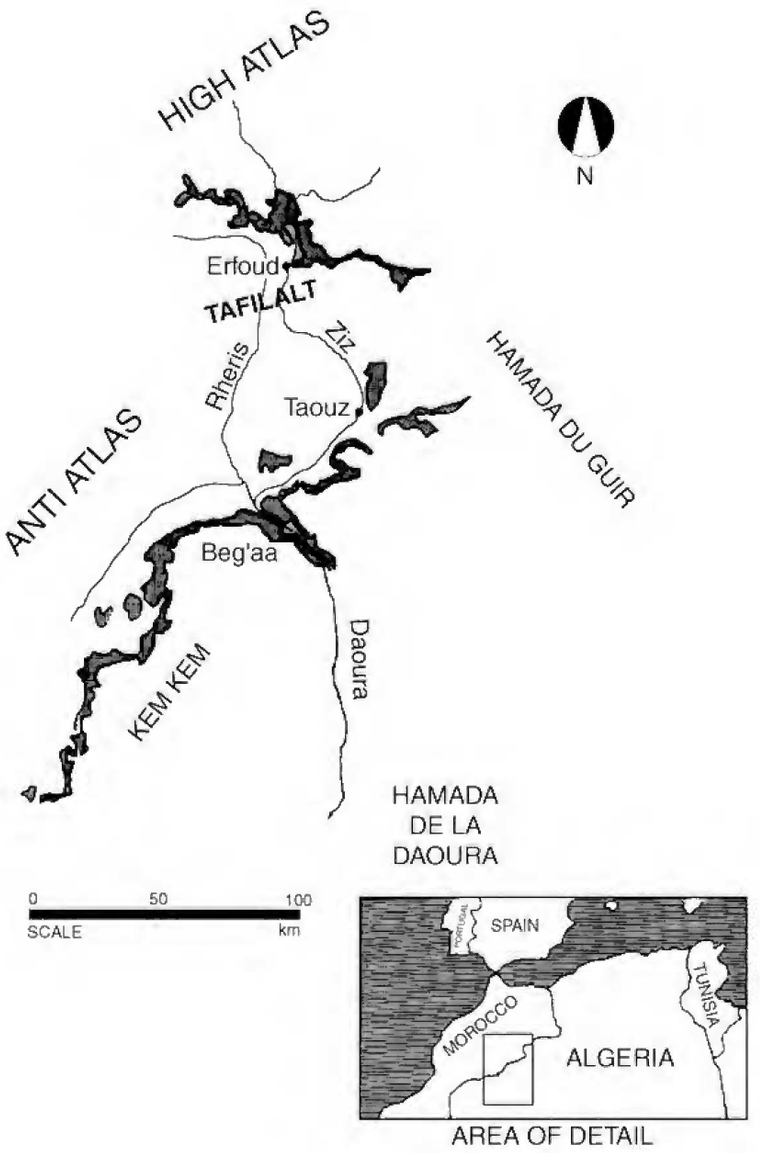



Fig.1- Map of Southern Morocco (Province of Ksar es Souk), showing the distribuition of Cretaceous deposits (stippled). Modified from RUSSEL (1996).

spine is partially broken, and so are the distal ends of the transverse processes. Its overall dimensions (Tab.1) indicate that it belonged to an animal similar in size to a swan, *Anser cygnoides* Linnaeus, 1758 (Dante Martins Teixeira, Museu Nacional - Rio de Janeiro, pers. comm.). In several places the external surface of the bone is broken away showing that the vertebra is light and pneumatized, although not to the same degree as in modern birds.

The centrum is elongated, amphicoelous, cylindrical, and slightly constricted medially. Its ventral margin is arched upwards and no pleurocoels or foramina are present on the lateral surface (Figs.2-3). The articular facets of the centrum are concave and have a subcircular outline with the dorsal margin tending to be straight and the ventral margin pointed. The neural canal is comparatively large (Figs.4-7), wider mediolaterally than high dorsoventrally (Tab.1), and exhibits a ratio height of neural canal to the height of cranial surface of the centrum of 0.67 (Figs.4-5). Within the neural canal, on the dorsal surface of the centrum, is a longitudinal ridge bordered laterally on each side by a groove. This structure, whose function is not known, does not reach the articular surfaces.

The neural arch is not very tall. The neural spine is elongated anteroposteriorly and exhibits a marked groove both cranially and caudally. There is a prominent lateral crest (*crista transversa obliqua*) that extends from the anterior proximal end of the transverse process to the base of the neural spine (Figs.4-5). The transverse processes are broken; no pre- or postzygapophysis are preserved. On the left side, a small prominence may represent the base of the parapophysis. A well-developed ridge is present on the anterior surface of the neural arch (the base for the *ligamentum elasticum interlaminare*). One lateral opening is observed on the base of the neural arch, likely representing the *foramen transversarium* (Figs.4-5).

## DISCUSSION

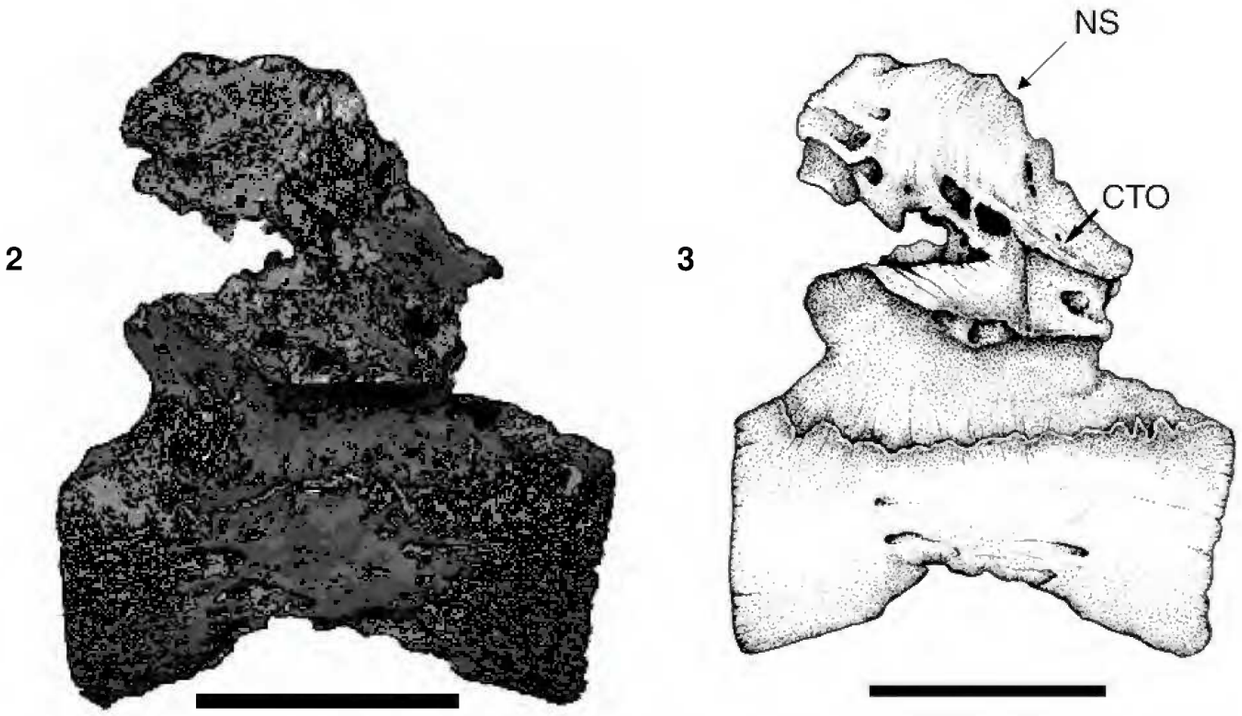
The main avian feature of this vertebra is the large neural canal, a synapomorphy of Aves (CHIAPPE & CALVO, 1994). In the dorsal vertebrae of the extant birds, the proportion of the height of the neural canal to the height to cranial articular facet varies from 0.55 to 2.75mm, while in non-avian theropods, it is less than 0.4 (CHIAPPE, 1996). As pointed out the proportion of CMN 50852 is 0.67mm, indicating that this specimen represents an avian taxon.

Since the specimen here is composed of one dorsal vertebra, comparisons with other Mesozoic birds is limited. The vertebra lacks the deep lateral excavations present in the Ichthyornithiformes (MARTIN & TATE, 1976), and its strongly amphicoelic centrum differs from the heterocoelic dorsals of Hesperornithiformes (MARTIN & TATE, 1976). The amphicoelic centrum also distinguishes the Moroccan specimen from the amphiplatyan dorsals of confuciusornithids (CHIAPPE *et al.*, 1999).

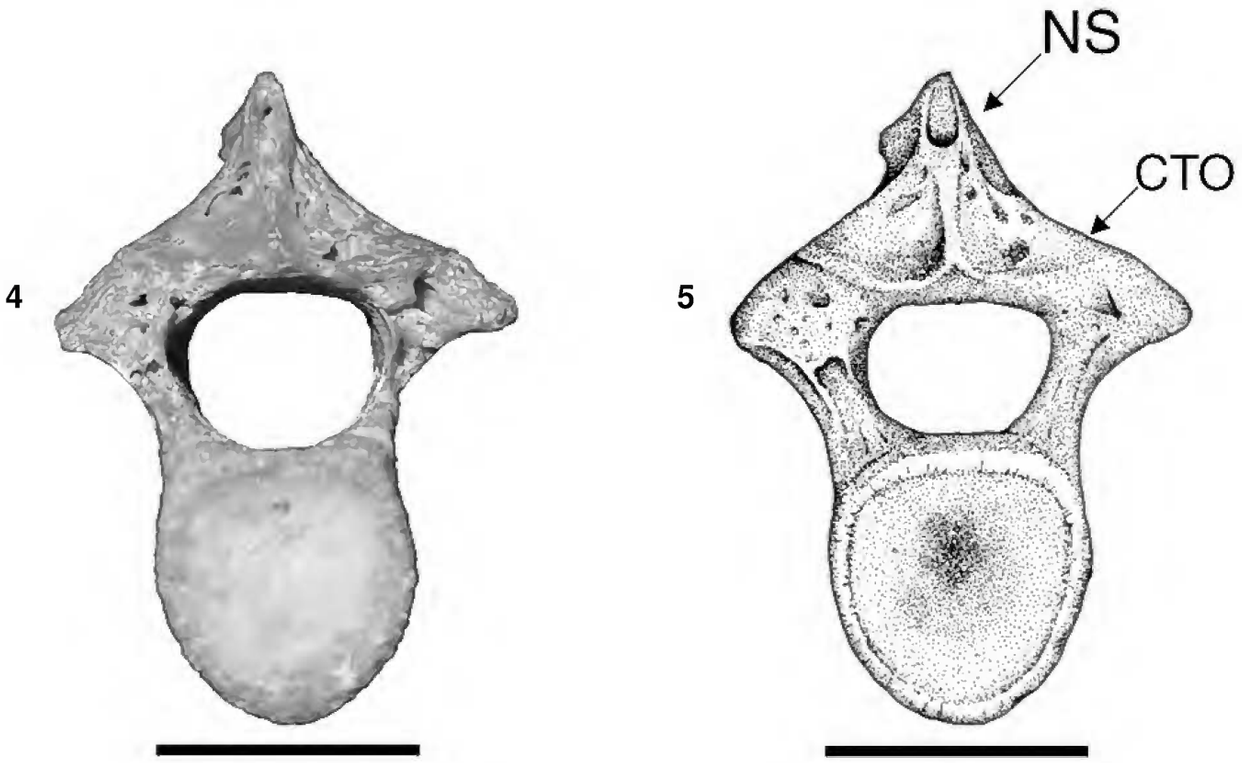
The Moroccan specimen also shows no particular affinities with the avian taxa thus far recorded from Gondwana. None of the dorsal vertebrae of *Patagopteryx deferrariisi* Alvarenga & Bonaparte, 1992 are amphicoelous (ALVARENGA & BONAPARTE, 1992)

Table 1. Measurements (mm) of CMN 50852, isolated avian vertebra.

| FEATURES | SIZE |
|---|---|
| Maximum length of the centrum | 21.0 |
| Maximum preserved width of the neural arch | 17.2 |
| Maximum width of the centrum (mid-portion) | 8.6 |
| Minimum width of the centrum (mid-portion) | 6.2 |
| Preserved height of the vertebrae | 25.6 |
| Maximum height of cranial surface of the centrum | 10.2 |
| Maximum height of caudal surface of the centrum | 10.0 |
| Maximum width of cranial surface of the centrum | 9.3 |
| Maximum width of caudal surface of the centrum | 9.7 |
| Maximum height of the neural canal | 6.8 |
| Maximum width of the neural canal | 8.0 |
| Ratio height neural canal/ height cranial surface of the centrum | 0.67 |



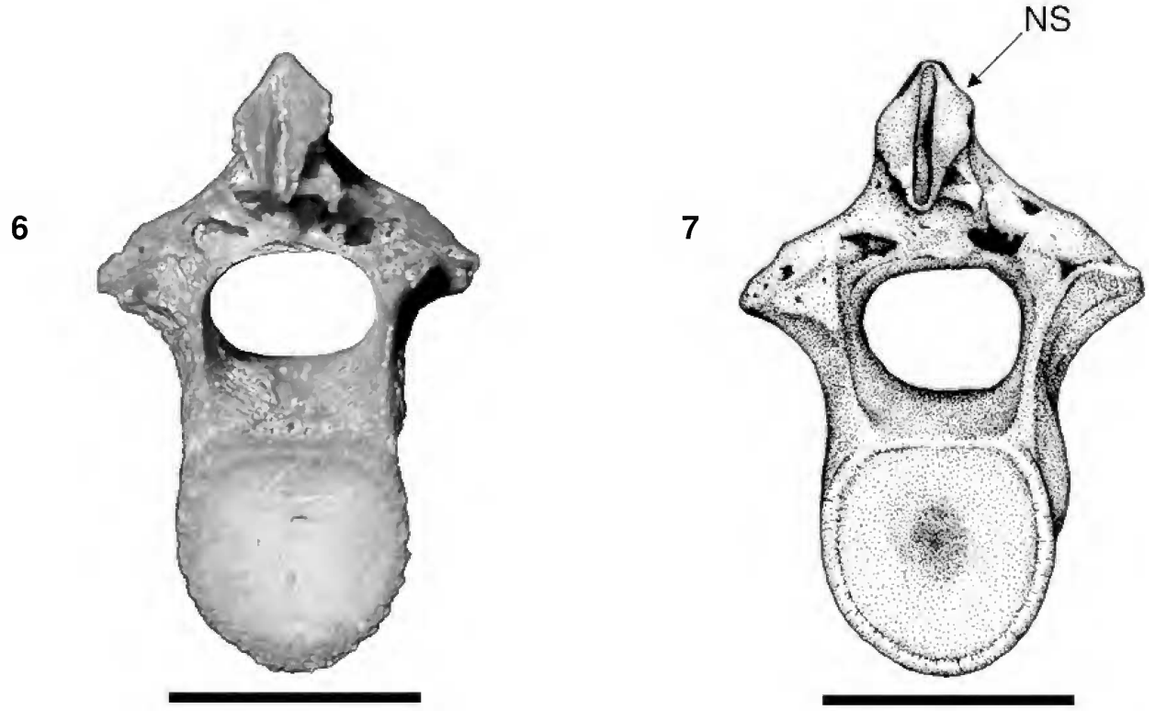

Right lateral view of the avian vertebra (CMN 50852) from the Cretaceous strata of Morocco; fig.2- picture; fig.3- drawing. (CTO) *crista transversa obliqua*, (NS) neural spine. Scale bar = 10mm.




Cranial view of the avian vertebra (CMN 50852) from the Cretaceous strata of Morocco: fig.4-picture, fig.5- drawing. (CTO) *crista transversa obliqua*, (NS) neural spine. Scale bar = 10mm.

and the dorsals of Enantiornithes are roughly amphiplatyan, with remarkably compressed vertebral bodies and a prominent lateral axial groove on the centrum. Furthermore, the parapophysis in the Enantiornithes is situated on the medial part of the centrum (CHIAPPE, 1996).

Regarding the size of the neural canal, the Moroccan specimen shows similarities with the Alvarezsauridae, which is composed of *Alvarezsaurus calvoi* Bonaparte,1991, *Mononykus olecranus* (Perle, Norell, Chiappe & Clark, 1993) and *Patagonykus puertai* Novas, 1997. The proportion of the height of the neural canal to the height of the cranial articular facet in *Mononykus olecranus* lies between 0.75-0.58mm and in *Patagonykus puertai* is 0.45mm (CHIAPPE, NORELL & CLARK, 1997). Although the neural canal of the dorsals in *Alvarezsaurus calvoi* is not prepared, this taxon also has a large neural canal (A.W.A.Kellner, Museu Nacional, pers. obs., 2002). The main problem here is the controversial position of the Alvarezsauridae in theropod phylogeny, with some authors regarding it a member of Aves (*e.g.*, NOVAS, 1996; CHIAPPE, NORELL & CLARK, 1997) and others as non-avian theropods, closely related with ornithomimids (BONAPARTE, 1991; MARTIN, 1995; SERENO, 1999) or as a basal Maniraptora (NORELL, CLARK & MAKOVICKY, 2001). If the latter is confirmed, than the large size of the neural canal might have arisen independently in alvarezsaurids and birds. In any case the main difference between the Moroccan specimen and alvarezsaurids is that the dorsal vertebra is less compressed laterally and lacks a pronounced ventral keel, the latter very developed in *Mononykus olecranus* and to a lesser degree in *Alvarezsaurus calvoi* and *Patagonykus puertai* (PERLE *et al.*, 1994; NOVAS, 1996, 1997). CMN 50852 further differs from *Patagonykus* by the absence of a lateral excavation and by being less compressed dorsoventrally. Despite the fact that the preservation of the dorsal vertebrae of *Alvarezsaurus* does not permit an adequate comparison with the specimen described here, the Argentinean taxon shows only a vestigial neural spine (BONAPARTE, 1991) and therefore is less developed than in CMN 50852. Furthermore, the Moroccan specimen is strongly amphicoelic contrasting to the subamphicoelic centra (with pleurocoels) of *Alvarezsaurus calvoi* (BONAPARTE, 1991), the opisthocoelic (except one that is biconvex) cervicodorsals and dorsal vertebrae of




Caudal view of the avian vertebra (CMN 50852) from the Cretaceous strata of Morocco: fig.6- picture, fig.7- drawing. (NS) neural spine. Scale bar = 10mm.

*Mononykus olecranus* (PERLE *et al.*, 1994), and the slightly concave (tending to the procoelic condition) of the sole dorsal known for *Patagonykus puertai* (NOVAS, 1996, 1997).

Overall, the Moroccan specimen is most similar to the dorsal vertebrae of *Rahona ostromi* Forster, Sampson, Chiappe & Krause, 1998, from the Late Cretaceous of Madagascar. This taxon forms a basal clade within Aves, one node above *Archaeopteryx lithographica* v. Meyer, 1861, or as its sister-group (FORSTER *et al.*, 1998). The dorsal vertebrae of *Rahona ostromi* are strongly amphicoelous with an arched centrum and neural spines of the same form than the Moroccan vertebra. The Morrocan specimen differs by being comparatively longer, having a proportionally larger neural canal and by the absence pleurocoels, suggesting that it belongs to a different taxon than *Rahona ostromi.*

## CONCLUSIONS

Overall, the record of fossil Mesozoic birds from Gondwana is scanty, particularly from Africa. Until now, the few African osteological specimens come from Madagascar. To our knowledge, the Moroccan specimen is the second osteological evidence of Mesozoic birds in northern Gondwana (besides the occurrence in Lebanon, DALLA VECCHIA & CHIAPPE, 2003). Its closest affinities lie with *Rahona ostromi*, although the Moroccan specimen represents an unknown basal avian group, increasing the diversity of this clade.

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